Acronym: VO2max

Title: Evaluation of Maximal Oxygen Uptake and Submaximal Estimates of VO_2max Before, During, and After Long Duration International Space Station Missions

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Increment(s) Assigned: 19, 20

Brief Research Summary (PAO): Evaluation of Maximal Oxygen Uptake and Submaximal Estimates of VO_2max Before, During, and After Long Duration International Space Station Missions (VO_2max) will document changes in maximum oxygen uptake for crewmembers onboard the International Space Station (ISS) on long-duration missions, greater than 90 days. This investigation will establish the characteristics of VO_2max during flight and assess the validity of the current methods of tracking aerobic capacity change during and following the ISS missions.

Research Summary:

- VO_2max, sometimes referred to as VO_2peak, is the standard measure of aerobic capacity and is directly related to the physical working capacity of an individual. VO_2max is related to the ability to perform an egress task while wearing a Launch and Escape space suit; therefore, decreased VO_2max may represent a safety concern in the event of an emergency during space flight.

- Evaluation of Maximal Oxygen Uptake and Submaximal Estimates of VO_2max Before, During, and After Long Duration International Space Station Missions (VO_2max) allows for measurement of actual VO_2max as opposed to the estimation methodology previously used in order to gain more insight into the aerobic capacities of the crewmembers onboard the ISS.

- By understanding the changes in VO_2max that occur within space flight, necessary adjustments can be made to EVA exercise countermeasures.

Detailed Research Description: In 2006, National Aeronautics and Space Administration (NASA) identified gaps in the scientific and medical knowledge regarding the human response to space flight. One of the gaps identified was the direct measurement of maximum oxygen uptake (VO_2max) during and after long-duration space flight. Reduced VO_2max will cause a diminished capacity to perform strenuous physical tasks such as those required during extended EVAs while performing structure assembly tasks. VO_2max has never been assessed during or after long-duration space flight, nor have the estimation methods currently used by NASA to track changes in aerobic fitness during space flight been validated on orbit. Therefore, the Evaluation of Maximal Oxygen Uptake and Submaximal Estimates of VO2max Before, During, and After Long Duration International Space Station Missions (VO_2max) investigation will measure VO2max during and following long-duration missions and assess the validity of using submaximal measurements of heart rate (HR) and oxygen consumption (VO_2) to track changes in aerobic capacity. In addition, non-invasive measurements of cardiac output (Qc) will be performed during exercise to determine if measurement of Qc will improve the accuracy of the submaximal estimations of VO_2max.

For this investigation, crewmembers participating in the ISS missions greater than or equal to 90 days will perform graded cycle exercise tests to maximum effort levels prior to, every 30 days during, and following flight. Measurements obtained during these tests will include HR, VO_2, and Qc. During these tests ECG will be monitored real-time as a safety precaution.

It is expected that the results from the VO_2max investigation will include accurate VO_2max measurements from crewmembers participating in long-duration space flight and observation of the pattern of change across mission duration. Additionally, the evaluation will allow NASA to determine if submaximal exercise testing data will provide results that allow accurate estimation of the crewmembers' aerobic capacity during and after space flight. Data from this experiment will be shared with NASA Medical Operations to refine future test requirements and optimize the testing used to track aerobic capacity during and after space flight.

Project Type: Payload

Images and Captions:

NASA Image: ISSE01356862 - NASA ISS Science Officer Jeff Williams assisting Flight Engineer-2, Thomas Reiter performing his PFE-OUM on the CEVIS during ISS Expedition 13. A similar protocol will be used to measure VO_2max.

Operations Location: ISS Inflight

Brief Research Operations:

- The crewmembers will exercise using a Cycle Ergometer with Vibration Isolation and Stabilization (CEVIS), cycle ergometer while being monitored for:
    - heart rate
    - blood pressure
    - workload
    - perception of effort
    - VO_2 (volume of oxygen utilized)
    - VCO_2 (volume of carbon dioxide production)
    - Qc (cardiac output)
- The values obtained during preflight testing will determine a protocol to follow for all further testing preflight, inflight, and postflight.

- The crew surgeon will monitor all tests via real-time data downlink during the inflight test sessions.

Operational Requirements: The VO_2 max experiment requires a subject count of 12. Those crewmembers whose maximum workload exceeds 300 watts during preflight testing will be excluded because the CEVIS on ISS is limited to a max workload of 350 watts. The preflight portion will occur at L-270 and L-60 with a back-up pre-flight session at L-30, if required. The inflight portion begins at flight day 15 and repeats every 30 days for the duration of the increment. There is a postflight portion occurring at R+1 and R+10 with a possible R+30 session pending crew surgeon and investigator discretion. There is a requirement for real-time data downlink during the exercise protocol.

Operational Protocols: Activities for this investigation will occur preflight, inflight and postflight.

- Preflight
    - At launch -270 days (L-270) an upright cycle ergometer test will establish peak heart rate and VO_2. Additional measures include blood pressure, workload, and perception of effort. The values obtained from this test will be used to establish the work rates for all further testing sessions.
    - The L-60 days test will serve as the first test the subject performs using their specific protocol. Measures of VO_2, VCO_2, heart rate, Qc, blood pressure, workload and rating of perceived exertion are obtained. If the data from this test is judged not technically acceptable, this test will be repeated at L-30.
- Inflight
    - On flight day 15 (FD15) and every 30-days thereafter, crewmembers set up the Portable Pulmonary Function System (PPFS), Cycle Ergometer with Vibration Isolation and Stabilization (CEVIS), and associated hardware. The crewmember will exercise using the CEVIS and will inspire cabin air and expire through a mouthpiece while their nostrils are occluded with a nose clip. The Portable PFS will be used to calculate or monitor VO_2, VCO_2, heart rate, Qc, blood pressure, and workload. Real-time data downlink will be required during the exercise protocol. Health and status data will be acquired real-time depending on Ku coverage; otherwise, all data is stored on the PPFS for downlink following the session.
- Postflight
    - At return plus 1-day (R+1), tests identical to the preflight L-60 and L-30 tests will be performed. Measurements will include VO_2, VCO_2, heart rate, Qc, blood pressure, workload and rating of perceived exertion.
    - The test performed on R+10 will be identical to tests performed at L-60, L-30, and R+1.
    - The final test performed at R+30 will be identical to tests performed at L-60, L-30, R+1, and R+10. This test may be waived by the investigator and crew surgeon if data obtained from the R+10 session indicates the crewmember's aerobic capacity has returned to preflight levels.

Review Cycle Status: PI Reviewed

Category: Human Research and Countermeasure Development for Exploration

Sub-Category: Cardiovascular and Respiratory Systems

Space Applications: The results from this experiment will provide NASA and the ISS International Partners definitive data to determine if submaximal exercise testing provides an accurate assessment of aerobic capacity during and following long-duration space flight.

Earth Applications: Little information is currently available on the effects of long-term exposure to a closed life control system microgravity environment on aerobic capacity of humans. This information is important to maintain crew health during long-duration exploration. The data will also provide valuable insight into the aerobic capacity of teams in closed environments on Earth, such as arctic bases and submarines.

Manifest Status: Planned

Supporting Organization: Exploration Systems Mission Directorate (ESMD)

Previous Missions: This expedition will be the first time the VO_2max investigation is performed on orbit.

Related Publications:
Lee SMC, Moore AD, Barrows LK, Fortney SM, Greenisen MC. Variability of Prediction of Maximal Oxygen Consumption on the Cycle Ergometer Using Standard Equations. NASA TP 3412. Washington, D.C.: National Aeronautics and Space Administration. 1993 .

Levine BD, Lane LD, Watenpaugh DE, Gaffney FA, Buckey JC, Blomqvist CG. Maximal exercise performance after adaptation to Microgravity. Journal of Applied Physiology. 1996 ; 81(2): 686-94.

Moore AD Jr, Lee SM, Charles JB, Greenisen MC, Schneider SM. Maximal exercise as a countermeasure to orthostatic intolerance after spaceflight. Medicine and Science in Sports and Exercise. 2001 ; 33(1):75-80.

Web Sites:
ISS Medical Project

Related Payload(s): PFE-OUM

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